THE RELIEF OF OUR PACIFIC COAST[1]

Ever since the landing of the Pilgrims on Plymouth Rock and the founding of Jamestown, if not even in the Garden of Eden, "Westward Ho" has been the cry, and the inspiration of this call of the wild is well portrayed by Leutze in his famous painting at the national capitol.

"Westward the Star of Empire takes its way" is no less true to-day than two centuries ago, but from a more commercial point of view.

The near sea level transcontinental water route of the Panama Canal is in strong contrast with the bold relief of the immigrant route of the early days in wagons across the Great Plains and Rocky mountains, with the privations of the Great Basin to the ranges of the Pacific coast with luxuriant wealth of forest and field, affording the framework for the Golden Gate where the Panama-Pacific Exposition is about to celebrate the opening of the great canal.

Many a traveler will find his way from the Atlantic coast to California on that occasion, and to prepare him for the strong contrast between the surface features of the two ocean borders I have selected as my theme on this occasion "The Relief of Our Pacific Coast." It will indeed be a great relief to the generous heart of the Pacific coast to welcome a large number of visitors to the Panama-Pacific Exposition, but that is not the relief to which I refer. It is to the form of the land surface, its ups and downs with reference to the sea level along our Pacific coast, that your attention is invited. It is the subject which in one form or another has held my attention as a field of investigation in connection with the United States Geological Survey for many years. Do not be dismayed at this length of service as affording a suggestion of the duration of this discourse. But quite the contrary, the proportion should be inverse, for it seems quite probable that my eminent predecessor, Professor Lesley, was right when he declared that geologists talk too much, and I shall heed his admonition.

The backbone of the North American continent is in the Rocky Mountain system relatively near the Pacific coast. The great valley of the Mississippi lies to the east with the Appalachians and the coastal plain of the Atlantic States beyond. A 200-mile wide belt on the Atlantic coast, at least from Virginia southward, is a coastal plain and piedmont region without mountains or even big hills, but on the Pacific coast the 200-mile belt is mountainous in the extreme from Canada to Mexico.

The mountain belt of the Pacific coast is but a member of that merged group of mountain systems, the Cordilleran, that runs through the western United States and Mexico and forms the continental bond of Panama, now so happily pierced for the commerce of the world and so fittingly and attractively celebrated in the Panama-Pacific Exposition.

Indeed, it is believed that the mountain belt of our Pacific coast is no small part of the attraction to the exposition. It constitutes not only the framework of the Golden Gate, the scene of the great event, but in itself embraces some of the finest scenic features of the world among which are four national parks, the Yosemite, General Grant, Crater lake, and Mount Rainier, besides three national monuments, the Pinnacles and Cinder Cone in California, the caves of Oregon, and Mount Olympus in Washington, all districts of

[1] Address of the Vice-president and Chairman of Section of Geology and Geography, American Association for the Advancement of Science, Philadelphia meeting, December, 1914. Published with the permission of the Director of the U. S. Geological Survey.

profound geologic and geographic interest and each so distinctive as to be especially attractive.

The relief of a country may be expressed in terms of water power, and considering the rainfall the water power is proportional to the relief. From this point of view the Pacific coast relief is greatly in excess of an equal area of the Atlantic coast.

The area of the direct drainage into the ocean from the Atlantic States is approximately 284,000 square miles,[2] while that into the Pacific, not counting the Colorado River, is about one fourth greater than that of our Atlantic coast, and yet the energy represented by the Pacific drainage is more than seven times that of the Atlantic coast. By far the greater portion is undeveloped and gives some idea of the latent possibilities of the empire of our west. Attention should be called to the fact, however, that much of the Pacific coast power is in the Columbia river, of which the greater part lies east of the mountain belt, but, even excluding that portion of the Columbia, the enormous power of the mountain belt greatly exceeds that of an equal area along our Atlantic coast.

With this may be coupled also that of the production of precious metals, which are vein deposits formed as an adjunct of stresses that express themselves in relief. The production of precious metals in the mountain belt of the Pacific coast in recent years has been hundreds of times that of the Atlantic States.

The mountain-building period on the Pacific coast bordering the larger ocean may have been longer and more intense than that on the Atlantic, resulting in greater and perhaps later segregation, so that erosion has not removed the mountains, as has been the case upon the Atlantic side.

That this is not simply a matter of time, but of actual deformation and uplift, may be inferred from the enormous deposits of limestone and coal to the east, which indicate not only a region of low relief but low relief of wide extent. Strengthening the contrast in the relief of the coasts but balances the values of the mineral deposits.

PACIFIC COAST MOUNTAIN BELT

The continental feature bordering the Pacific coast of the United States is a mountainous belt of surpassing grandeur. Lying between the Great Basin platform of the interior on the east and the Pacific ocean on the west, it is the crushed and upheaved edge of the continent along the line of counter stress between the land and sea. The great upfolds of the earth's surface in that region are so young as to preserve much of the prominent form and mass resulting from the deformation.

It is remarkable for its lineal continuity, with a width ranging from 100 to 200 miles throughout a length of 2,500 miles. Some of it indeed at both the northern and southern ends is below sea level, but other portions, especially in California, Oregon and Washington, bear the highest peaks in the United States south of Alaska.

The general form of the belt is slightly sigmoid with a broad coastal curve to the west in northern California and to the east at the international boundary (49th par.), resulting from large structural features which will appear in an analysis of the members of the belt.

The general features of the belt are two lines or ranges of mountain elevations with a great valley between. For the most part the two lines of mountains appear to be parallel with each other and the coast; the Sierra Nevada and the Cascade ranges on

[2] Water Resources Paper No. 234, pp. 52–57.

the east and the coast ranges, including the Klamath mountains of California and Oregon and the Olympic mountains of Washington on the west from near the Mexican line to British Columbia. They are separated by a depression, a great valley more or less continuous from the Gulf of California and Salton Sea on the south through the Great Valley of California, the Willamette Valley of Oregon and Puget Sound to Georgian strait on the north, which it enters and follows with less definition along the coast of British Columbia to Alaska, a total distance of about 2,500 miles.

In the United States there are only three rivers, the Columbia, the Klamath and the Sacramento (including the Pit), which cut across the entire mountain belt from the interior platform to the sea, although three others, the Chehalis, Umpqua and Rogue rivers, rise on the west slope of the Cascade range and break through the coast range.

The mountain ranges which now constitute the topographic limits of the Great Valley of the Pacific coast are composed of parts that differ widely in origin, age and composition.

THE SIERRA NEVADA

The Sierra Nevada is a massive mountain block, 350 miles long and 80 miles wide, with a long gentle slope west to the Great Valley, and to the east has a short steep slope, due to faulting, that separates the rocks of the Sierra from those of the Great Basin.

The Sierra Nevada is composed of sedimentary and igneous rocks of various ages, from Silurian to Jurassic, which have been closely folded and intruded by batholithic masses of granitic rocks. The folding and intrusion have greatly altered the rocks and developed in them numerous metalliferous veins, chiefly of auriferous quartz. During a long period of erosion which washed away the mountains and reduced the country to low relief the veins gave rise to auriferous gravels, and some of the earlier of these gravels in the northern portion of the range are covered by flows of Tertiary lavas.

The southern and central portion of the range where granodiorite prevails is one great topographic block bounded on the east by a fault zone, which curving to the west around the southern end, meets the San Andreas fault of recent earthquake fame and brings the Sierra Nevada and the Coast range together. In the northern portion of the range along the eastern side of the great block, adjoining the Great Basin and suggesting its structure, there are two smaller fault blocks, one of which locally has sunk for Lake Tahoe, while the other forms the bold eastern escarpment of the range.

The Tertiary lavas of the Sierra Nevada are continuous to the northward with the great pile of volcanics in the Cascade range, beneath which the older terranes of the Sierra Nevada disappear with a strike of approximately N. 50° W. toward the Klamath mountains, about 60 miles away. Some minor faults appear in the lavas of the Lassen Peak region but major faults like those which characterize the Sierra Nevada have not yet been recognized in the Cascade range.

The faulting which limits the Sierra Nevada on the east, as emphasized recently by Ransome, has been of long duration and is still in progress, as evidenced by the many small earthquakes at points along its course. The Owens Valley earthquake of 1872 is the most notable example resulting from a fault of 10 feet.

The earthquake was widely felt, but there are many that are not felt at all under

ordinary circumstances, and yet may be clearly detected and their intensity and duration measured by a seismograph. Every earthquake indicates a change in the relative position of the rocks, however small, either horizontal or vertical or both, and consequently in the relief of the country. It may truly be said that the mountains are growing. In no other part of the United States is there as great seismic activity as along our Pacific coast, a fact which means that the mountains are not only growing, but growing faster than elsewhere in the United States. Some are growing less, others greater, and there is need, as pointed out by Lawson, of establishing bench marks on opposite sides along the faults, so that the amount and character of the change may be measured.

The transformation of the Sierra Nevada from a region of low relief to one of high relief so increased the river grades of its western slope that they have carved out deep canyons which now form the principal relief feature in the scenic attractions of the range. The Yosemite Valley is the finest example, although rivaled by that of Kern River, and is one of our most impressive and instructive national parks. This is especially the case since nature has made some of the finest trees in the region big in proportion, as if to correspond to the size of the canyon.

KLAMATH MOUNTAINS

The Klamath Mountains are an irregular half crescentic group of peaks and ridges along the coast in northwest California and southwest Oregon. The general shape is that of a saddler's knife, with the curved side to the west and the handle to the east, a little south of the center. Their greatest extent north and south is about 225 miles, with 75 to 115 miles in width. The crescentic border follows the coast for about 90 miles north from the mouth of Klamath River in California to near Rogue River in Oregon. To the northwest of the Klamath Mountains is the coast range of Oregon. To the southwest is the coast range of California, both overlapping the western curve of the Klamath Mountains along the coast. On the east lies the Rogue River Valley, Shasta Valley and Sacramento Valley bordered by the great lava field of the Cascade range.

The Klamath Mountains are composed chiefly of Carboniferous and Devonian sediments, with a large proportion of contemporaneous lava flows of rather basic types. Besides these there are large bodies of mica and hornblende schists of pre-Paleozoic age, as well as sediments and effusives belonging to the Jurassic and Triassic.

These rocks are folded, faulted and intruded by batholithic masses composed of granodiorite, gabbro and peridotitic rocks centering in a general core with aligned terminals that curve to the northeast in Oregon and southeast in California. The later sedimentary rocks of the Klamath Mountains, the Jurassic and Triassic, are richly fossiliferous in the Redding quadrangle, where they are associated with equally fossiliferous Carboniferous and Devonian strata that form the hills lying east of the Sacramento River and the railroad between Redding and Mt. Shasta. In the southern part of this exposure the Mesozoic rocks strike S. 50° E. in line with rocks of essentially the same age and position 75 miles away in the northern portion of the Sierra Nevada. To the northward in the Redding quadrangle we see these Mesozoic rocks curve to the right and strike to the northeast in the general direction of the Blue Mountains of Oregon. Now this change in the strike is not limited to the eastern portion of the Klamath Mountains

in the Redding quadrangle, but, more or less distinctly marked, it extends throughout the great stretch of the Paleozoic rocks of the whole group in both California and Oregon. Furthermore, the same curved trend is suggested by the form of the intruded masses. The mass of granodiorite between Lewiston and Igo extends southeast and widens directly toward the Sierra Nevada, where similar rocks are abundant.

While the composition and the plication of the rocks of the Klamath Mountains tend to show close relationship to the Sierra Nevada, it is only partial, and in reality the two are distinct, being separated in the first place by a wide depression probably due, as long ago pointed out by Whitney, to a fault across the trend of the range, and in the second place characterized by a series of overthrust faults quite unlike those which obtain in the Sierra Nevada.

Although the detailed structure of the Klamath Mountains has not been worked out, some of the major structures have been apprehended by Hershey and others sufficiently for consideration in this comparison of the several ranges of the Pacific coast chain.

The southwest limit of the Klamath Mountains against the coast range of California is marked by a profound thrust fault on which the highly crystalline schists of South Fork Mountain appear to have been thrust to the southwest up over the Cretaceous and Jurassic rocks toward the coast. The fault runs northwest and southeast and the hard schists give rise to a prominent long even-crested mountain ridge, one of the most conspicuous members of the Klamath Mountain group.

In Oregon a similar fault occurs through the Kerby region of Josephine County, where Devonian rocks are in effect thrust northwest toward the ocean up over those of Jurassic age. The fault runs northeast and southwest and erosion has developed prominent mountains facing the valley that lies to the northwest.

The Kerby fault if continued southwest in the same strike would intersect the South Fork Mountain fault, but, according to Hershey, before it reaches the South Fork Mountain fault it curves to the south and finally southeast so as to parallel the South Fork Mountain fault.

Farther east there is another fault belt which at the south end in California trends southeast, while at the northern end in Oregon its course is to the northeast. Like the other, it appears to be a thrust fault. Hershey has estimated the overthrust locally in one of the Klamath Mountain faults as much as a mile.

The curved thrust faults traversing the Klamath Mountains are in strong contrast with the normal faults of the Sierra Nevada. The Klamath Mountain thrust is to the westward. The downthrow of the normal faults in the Sierra Nevada is to the eastward. Thrust faulting occurs also locally in the Sierra Nevada, but at Taylorsville the thrust is to the eastward.

The Klamath Mountains are insular in character. Composed largely of Paleozoic rocks and surrounded by rocks of later age, they formed a buttress in the development of the coast ranges of California and Oregon. From the Sierra Nevada they are separated by a depression in the older rocks that extends northward beneath the Cascade range.

During a portion of the Cretaceous the Klamath Mountains were above sea level, but the gradual subsidence of the land almost or quite completely immersed them at the close of the Chico epoch, as shown by the rather widespread occurrence of fossiliferous fragments of sandstone from the Chico formation in the auriferous gravels of that region. During the early Ter-

tiary the region was a lowland of gentle relief cut down like the Sierra Nevada to a peneplain, but later it was raised as perhaps the great valley sank, and became a prominent mountain group.

THE COAST RANGE OF CALIFORNIA

The coast range of California lacks the wealth of precious metals found in the Sierra Nevada, and for that reason until recently it has not received so much attention from geologists. But the discovery of oil and its development has greatly stimulated research in that field. Only a few districts have been surveyed in detail and published, but much general reconnaissance has been done. What we know of the composition, structure and history of the range has been admirably summarized by A. C. Lawson and Ralph Arnold. Their summaries have recently been discussed in a most helpful critical way by Ransome, who is himself familiar with portions of the region.

The coast range of California, according to Lawson, extends from the Mexican boundary to near the mouth of Klamath River, with a length of about 720 miles, a width ranging from 40 to 60 miles, and a general trend of N. 30° W.

At the northern end Lawson includes the South Fork Mountain in the coast range, but it seems to me that the great fault on the western slope of South Fork Mountain is the delimiting feature and keeps the South Fork Mountain and Yallo Bally in the Klamath group.

The coast range is regarded by some, and Ransome among them, as ending on the south at the headwaters of Santa Maria River where the Tehachapi range joins the southern terminus of the coast range to the Sierra Nevada.

South of the Santa Maria River is a group of ridges including the San Rafael, Santa Barbara, Santa Ynez, San Gabriel, San Bernardino and other ranges, which, although not strictly parallel, have a general trend nearly east and west. These ranges embrace the Los Angeles country and have been most appropriately referred to by Ransome as the Sierra de Los Angeles.

The coast range throughout is composed of a succession of parallel ridges which, south from San Francisco to Santa Maria River, trend about N. 43° W., while in the northern portion of the range the trend is N. 26° W., giving an average course of N. 30° W. for this portion of the range. Everywhere the course of the ridges is more or less oblique to the coast line, which is made up of a series of zigzags that Lawson regards as probably due to faulting parallel and transverse to the ridges, thus cutting them off on the shore and affording excellent exposures of the composition and structure of the range.

The coast range of California is composed chiefly of Mesozoic and Tertiary rocks, with some that are older, as well as a considerable portion that belong to the Pleistocene. The oldest rocks are marble, quartzite, mica and hornblende schists like those of the Klamath Mountains and Sierra Nevada. They appear mainly as inclusions in the granitic rocks which form the concealed basement of the coast range and upon which was deposited unconformably the Franciscan formation, a complex succession composed in the main of strongly indurated sandstone with subordinate quantities of shale and conglomerate, a considerable part of radiolarian chert and foraminiferal limestone. In the upper part of the formation are interbedded lavas, and the whole is intruded by peridotite and basalt. A thick series (29,000 feet) of shales, sandstones and conglomerate of Cretaceous age follow unconformably on the crushed Franciscan and are succeeded by an extensive

succession of shales, sandstones and conglomerates of Tertiary and Quaternary age.

In composition the coast range is in strong contrast with the Sierra Nevada, being much the younger. There are great differences in structure also. The rocks of the coast range are folded, as Lawson points out, in rather sharp synclines and anticlines, some of which are overturned, as in the Monte Diablo region, toward the ocean and thrust faulted, but they are never so closely appressed as to indicate general and important deformation of the internal structure of the rocks affected. There has been no development of slaty cleavage or schistosity. In general, the axes of the folds are northwest-southeast, and although the minor folds may be more or less divergent, the major folds are parallel and extend for many miles. The coincidence of many of the larger valleys with a synclinal axis is very marked.

The coast range throughout is a faulted range and the faulting has had even more to do with the form of the relief than the folding. Many of the valleys are fault valleys with unsymmetrical slopes, the fault lying near the steeper slope. The faults, too, are especially interesting because of the earthquakes they produce. Faulting is still in progress, and each slip or movement along the fault plane results in a shock. The great earthquake of 1906 resulted from a slip along the San Andreas rift which has been traced for 600 miles. The movement was greatest in the neighborhood of San Francisco and chiefly horizontal instead of vertical, as is perhaps generally the case. Hundreds of faults slip and slight shocks occur in California every year, and perhaps hundreds more too gentle to attract attention.

The coast range as a whole may well be outlined by faulting. The steep bluff of the coast beneath the shallow and the deep sea is probably due to faulting, and the eastern side of the range in Tehama and Shasta Counties has a series of large sandstone dikes that evidently resulted from an earthquake, possibly in Tertiary time. Unlike the Sierra Nevada, which is mainly one great block tilted so that the streams consequent upon the tilting flow directly transverse to the range, the coast range is composed of many blocks with the main divide along the eastern edge, but the streams, instead of being wholly consequent, taking the shortest route directly to the ocean, are subsequent and follow the lines of easiest erosion along faults and folds to the sea.

According to Ransome, referring to the work of many others, the structure of the Sierra de Los Angeles appears to show a transition from a combination of folding and faulting such as is characteristic of the coast ranges to tilted block mountains, exemplified by the San Bernardino range, such as are characteristic of the Great Basin.

Much yet remains to be done before a comprehensive statement can be formulated concerning the structure of the coast ranges as a whole, but with the large corps of workers from the universities at Berkeley and Stanford and the United States Geological Survey as well as others in the field the detailed information is rapidly accumulating.

The coast route from Los Angeles to San Francisco is in the coast range throughout the entire trip and affords an excellent opportunity to observe many of its features.

THE COAST RANGE OF OREGON

If in California we have in the Pacific system two ranges, the Sierra Nevada and the coast range, which are strongly contrasted in composition, structure and age, in Oregon we have two ranges of still

greater contrast, not only in composition, structure and age, but in mode of development.

The coast range of Oregon extends from Cape Blanco in Oregon through Washington to the strait of Juan de Fuca, a distance of nearly 400 miles. At the southern end it abuts against or rather runs into the Klamath mountains without any sharp topographic termination. At the north it ends in the Olympic mountains of bold relief, reaching an altitude of 8,150 feet, but not quite reaching the height of the Klamath Mountains. South of the Columbia along its crest are Onion Peak, Saddle Mountain and Mary's Butte, of which several are volcanic.

On the whole the range is a unit but irregular and, as compared with the Sierra Nevada and coast range of California, is characterized by its lack of effect upon drainage. Although of small extent, it is cut across by four rivers, the Umpqua, Nehalen, Columbia and Chehalis.

It is composed wholly of Mesozoic and Tertiary rocks which at both ends abut against those of the Paleozoic age. The Franciscan series of sandstones, shales and cherts of Franciscan age, with serpentine and other intrusives, form a large part of the Olympics and a portion of the southern terminus of the range in Oregon, but have not been recognized in intermediate portions of the range. The same is true of the Cretaceous, especially the Upper Cretaceous, which lies with marked unconformity upon the rocks of Franciscan age and thus records the great diastrophic epoch of compression, probably about the close of the Jurassic.

The Cretaceous on the Pacific coast was a time of subsidence so profound, at least in one locality, as to result in the accumulation of 29,000 feet of deposits in a moderately shallow sea which transgressed the sinking land until it reached the base of the Sierra Nevada. In Oregon there was apparently a great embayment covering not only the northern end of the Klamath Mountains, but extending inland beyond the Cascade range to the base of the Blue Mountains. This great sinking embayment, as it were in the lee of the Klamath Mountains, the stable and insular terminus of the Sierra Nevada, is an important feature of both the Cascade and the coast ranges in Oregon. The steeper inclination of the Cretaceous strata as compared with the Eocene indicates their unconformity, and the discordance is the greater in proportion as the underlying Cretaceous is older.

The Eocene sandstones and shales, although mainly marine, are in part of fresh or brackish water accumulation and contain locally more or less important deposits of coal. They form the bulk of the coast range in Oregon and southwest Washington, and with them are associated in many places contemporaneous volcanics, for the most part basalts.

A large part of the coast range in Oregon and Washington south of the Olympics was probably not raised above the ocean before the close of the Eocene, but at that time the elevation became somewhat more pronounced, forming a low ridge which with minor oscillations admitted the Miocene sea through the gateway of the Chehalis and Columbia into the Willamette Valley.

Toward the southern end, where the Eocene contains some marine sandstones derived from the near shore of the Klamath Mountains, the coast range is gently synclinal. It presents a bold bluff with even crest to the Umpqua Valley, possibly due to a fault. Although, as a whole, the coast range of Oregon has not been subjected to as great compression as that of

California, nor cut into parallel ridges by large faults, yet in places along the coast, as at Coos Bay, the thinner bedded Eocene has been folded and compressed into a vertical position. The later intermittent uplift during the Quaternary is recorded by a series of elevated beaches cut more or less deeply on the west slope by the ocean waves.

THE CASCADE RANGE

The Cascade range is essentially a volcanic range stretching from Lassen Peak in California to Mt. Rainier in Washington, a distance of 450 miles. At both ends the lavas lap up on to the uplifted mountains of older rocks, the Sierra Nevada in California and the northern Cascades in Washington, but between these two from the Columbia River in Washington to the Pit River in California, for a distance of nearly 300 miles, the range is composed largely, if not wholly, of igneous rocks that have escaped from a great belt of volcanoes that form the range. The summit of the range is an irregular plateau strewn with many lava and cinder cones, of which each one marks the site of a volcanic orifice tributary to the upbuilding of the range.

Where best developed, as shown in the Klamath and Columbia river sections, the body of lava forming the range is on the average probably about 4,000 feet in thickness, but in the greater volcanoes like Hood, Jefferson, Mazama, Shasta and Lassen it rises to accumulations of 6 to 10,000 feet in thickness. The later foundations of the Cascade range were laid in the Oregon embayment during the Cretaceous and early Tertiary times, possibly before the ranges were distinctly outlined. The Tertiary volcanic effusions began in Oregon west of the Cascade range during the Eocene and possibly a little later in the same epoch eruptions began in the base of the Cascade range. During the later Tertiary the volcanic activity was greatest and the bulk of the range, though partly uplifted, was in equal or perhaps even greater measure upbuilt by flows of viscous andesitic lavas with much ejected material. Basalts are common and some acid lavas are known, but the great bulk of the range is andesite in strong contrast with the great lava plains east of the Cascades, where the thin basalt flows spread out horizontally like sheets of water. The change from the plain to the mountain slope at the eastern base of the Cascade range is abrupt and distinct, and due, for the most part, to the fact that the stiff viscous andesitic lavas were able to build up steep slopes while the superheated and highly liquid basalts spread out like water along the irregular mountain front.

After the close of the Tertiary the volcanic activity waned, although eruptions occurred to within the historic period and possibly even to the present day if the outbursts from the summit of Lassen Peak develop so as to involve molten material.

However that may be, there is no doubt that the Cinder Cone and its lava field 10 miles northeast of Lassen Peak resulted from one or more eruptions within a century or two. In 1843 both Baker and St. Helens were in violent eruption, ejecting large quantities of ashes, of which Fremont obtained samples collected at the time of the eruption. There is also well-attested authority that eruptions occurred on Mt. Baker in 1854, 1858 and 1870. In general, however, the volcanoes of the Cascade range are considered extinct, and the upbuilding of the Cascade range completed as far as the actual accumulation of lava is concerned.

While the great altitude of the range is due chiefly to the piling up of lavas, a considerable portion is due to actual uplift, for in the Cretaceous of the Rogue River valley

marine shells now occur at the elevation of 3,000 feet which must have been elevated to that amount. The same may be said of the Eocene. It is, however, important to note that the uplifting of the Cretaceous and Eocene sediments about the close of the Tertiary was connected with the Klamath Mountains rather than that of the Cascade range.

Faulting that has played so large a rôle in the development of the Sierra Nevada and the coast range of California has not given general features to the volcanic mass of the Cascade range. Small faults are common in the lavas southeast of Lassen Peak, forming lines of bluffs and bringing the ground water to the surface in large springs, a feature which is common also in the Klamath Lake region and, as pointed out by Russell, along other portions of the range, but these small faults have no effect on the general form of the range.

Along the western base of the range in the Willamette Valley, Washburne has pointed out some features suggesting a fault, but as yet its existence is a matter of doubt. There is no great relief feature in that region that appears to have originated in faulting. Farther south in the Rogue River valley there is a regular practically conformable succession from the Cretaceous through the Tertiary sediments to the overlying lavas of the Cascade range. Small faults occur in the Eocene coal beds which dip beneath the range but the faults are connected with the local intrusion of the lavas and not of large extent connected with the uplifting of the range.

While it is evident that the lavas of the Cascade range are faulted, I think Russell has greatly overestimated the effect of the faulting as a factor in the upbuilding of the range, which, as it seems to me, is a great pile chiefly of viscous andesitic lavas from many confluent cone-capped vents, in strong contrast to the coneless basalt plains in the formation of which the high degree of fluidity in the outflowing lava was the most important factor.

THE GREAT VALLEY

Of all the relief features of our Pacific coast mountain belt the least impressive and yet the most important is the Great Valley where live by far the larger number of people, with railroads for transportation, and produce from the alluvial soil washed in from the adjacent mountain ranges the main portion not only of their own subsistence, but much for other parts of the world. The great valley extends throughout the entire mountain system, but not without interruptions, and in fact these interruptions are so marked in certain localities, as between the heads of the Sacramento and Willamette rivers, where the valley is obscured by cross folds from the Klamath Mountains, that some geologists have doubted its continuity. When these cross folds and their effect upon the great valley are clearly understood it will be recognized that the valley is the great feature of the Pacific mountain belt, with its history deeply buried in and beneath an enormous mass of sediments.

J. S. DILLER

U. S. GEOLOGICAL SURVEY,
WASHINGTON, D. C.,
December 10, 1914

THE INTERNATIONAL COMMISSION ON BOUNDARY WATERS

MR. ADOLPH F. MEYER, associate professor of hydraulics in the college of engineering of the University of Minnesota, has been engaged as consulting engineer for the International Joint High Commission, in connection with investigations made on boundary waters. These investigations have extended over the past two and a half years, and in this work Professor Meyer has been associated with Mr.